Chapter 7

General Observations

Chapter Highlights

Treatment wetlands across Colorado are effectively treating wastewater and meeting discharge requirements.

Wetland cells are generally rectangular in shape. A few examples of wetlands with irregular borders provided increased aesthetic and wildlife habitat value without jeopardizing treatment capability.

Treatment wetlands can be designed to operate with negligible energy requirements.

Overview

The project team identified twenty constructed wetlands currently permitted to treat municipal wastewater. An on-site analysis was performed for each of these facilities. Of these sites 13 were surface flow wetlands, 5 were subsurface flow and 2 operated as a combination of surface and subsurface flow.

In addition to the municipal systems, a total of 8 on-site residential treatment, stormwater treatment and commercial wastewater treatment facilities were identified and visited. These wetland sites are discussed briefly in Chapter 6, but were not included in the more rigorous analyses applied to the municipal wastewater facilities.

The project team visited all 20 municipal systems in order to visually examine the systems. Each visit was merely a ‘snapshot in time’. As such, team members relied on treatment facility operators and data files to provide a comprehensive understanding of each system. Since this study was limited to existing data, CDPHE permit files were another important resource for providing a historical context for each system’s performance.

Discussed below are the compiled findings of the study.

Facility

The municipal treatment facilities in Colorado with wetland components utilize preliminary and primary forms of treatment before discharging into the wetland cells. The most prominent treatment process is the use of lagoons as primary treatment with the wetlands serving the function of secondary treatment. Septic tanks are another form of primary treatment used in a wetland treatment facility.

Lagoons

Shallow lagoon systems were a popular form of wastewater treatment at one time. The rationale behind using a shallow lagoon system included providing complete aeration of the shallow water column in order to provide a completely aerobic lagoon without the use of mechanical aerators. A problem encountered with these shallow lagoons is the excessive growth of algae that is carried over in the lagoon effluent. This algae carry-over results in exceedances of BOD and TSS limitations. The use of deeper lagoons allows the operator to vary the level of the discharge pipe in the water column in order to avoid algae growth and the sedimentation layer.

Septic Tanks

Overflow from septic tanks can be discharged into a wetland rather than traditionally used leach fields. Septic tanks remove solids and greases from the raw wastewater. All of the Colorado treatment wetlands utilizing septic tanks as primary treatment were subsurface flow systems.

Background

Interviews with operators and review of CDPHE files provided a historical context for each wetland site. Each site's background information was reviewed in order to answer the question 'why were wetlands chosen to be a part of the treatment system'. The following were the top reasons communities in Colorado have chosen wetland treatment systems.

Remediation of Noncompliance

Providing compliance for historically noncompliant systems is a common reason for retrofitting wastewater systems with a wetland component. Many of the sites visited had shallow lagoon systems with large algae blooms. These shallow lagoons do not have the ability to vary the depth from which water is pulled off the system, and therefore are prone to discharging algae particles. Adding wetland systems provided treatment for the algae carryover.

Aesthetic - Constructed wetlands blend into rural areas where traditional physical facilities would detract from the overall scenic beauty of a rural area.

Part of Mission - Colorado wetlands were also chosen in some areas due to their ability to fit in with an organization's overall mission and goals to promote natural processes. For example

Low Tech - Rural areas often lack the trained personnel to operate complex mechanical systems.

Retrofit - Abandoned lagoons can be retrofitted into a wetland system with minimal excavation work.

Energy

Treatment Components

The wetland systems themselves do not require electric or fuel sources of energy. All of the treatment wetlands in this inventory were designed to operate under gravity flow conditions with no mechanical devices needed for the wetland cells' treatment processes. Heavy equipment may be used once a year, or once every few years, for harvesting and removal of wetland plants. Most of the energy expended on the wetland systems is manual labor necessary for maintaining the system. The amount of electrical and fuel energy that these facilities require is determined by the other treatment components being used, such as aerators and mixers.

Lagoons

Of the 20 sites inventoried, 17 used lagoon systems for primary treatment. Of these 17 lagoon systems, all but one used mechanical aeration devices. Energy requirements for the aeration system depend on the horsepower of the aerators and the operating schedule adhered to. The operating schedule has a large impact on the efficiency of a system. For example, adhering to an operating practice in which the aerators are operated continuously during the winter months, and only 8 hours during the night in the summer months results in the aerators operating for 4800 hours per year. For a lagoon with five, 5hp aerators, this results in an energy consumption of approximately 90,000-kilowatt hours per year. In contrast, operating the same five aerators on a continuous basis year round results in an energy consumption of 163,000-kilowatt hours per year.

Septic Systems

Three of the facilities visited treated wastewater in septic tanks before release to the wetland cells. Energy expenditures with these systems are associated with lift stations in the collection system, rather than components of the treatment processes. All three of the facilities using septic tanks as preliminary treatment incorporated subsurface flow wetland cells into the treatment process. Sufficient hydraulic head was provided to allow gravity flow through the wetland cells.

Headworks

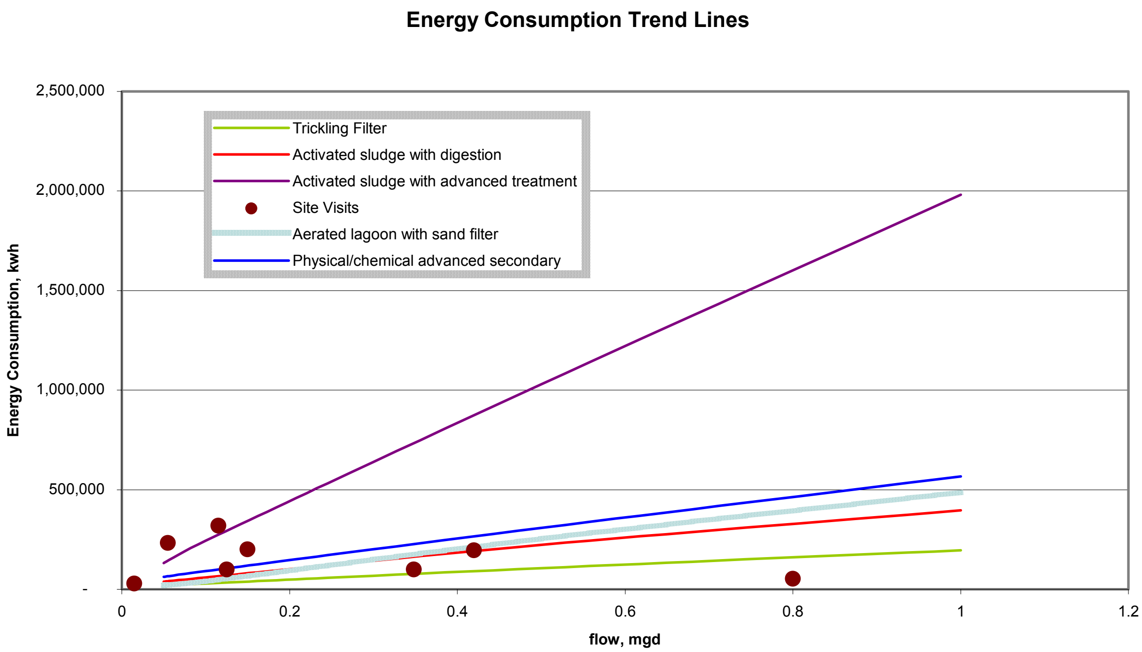
Facilities that receive non-traditional domestic wastewater may need to invest energy in pretreatment. Three of the Colorado treatment wetlands received prison wastewater. Solids-removal devices, such as grinders, are often necessary to remove items that are common in prison wastewater due to prisoners flushing items for protest purposes. These devices must operate continuously, and are large energy consumers.

Energy Costs

Typical utility bills were used to determine energy consumption for entire facilities. This energy consumption includes energy necessary to operate lighting, and miscellaneous uses of energy for measuring equipment and on-site office space. A typical utility bill for the sites visited is around $800 per month. At approximately six cents a kwh, this translates into an energy use of 13,300 kwh pr month, or 160,000 kwh per year.

Comparison to Other Treatment Methods

The energy consumption study undertaken by Middlebrooks (as discussed in Chapter 4) determined energy costs for different treatment methods based on the flow through the treatment facility. The figure below shows trend lines for some common treatment methods. The range of energy use by the facilities using wetlands is indicated on the graph.



The primary consumer of energy at these sites was the operation of aerators for primary treatment lagoons. The use of alternative energy sources, such as solar or wind energy, would reduce the energy consumption of these treatment facilities to near-negligible levels.

Operation and Maintenance

Typical man-hours

Operators typically spend about 2 hours a day at the treatment site. Maintenance includes annual harvesting and / or burning. The operator must maintain flow through the hydraulic system, which requires cleaning out pipes. Other maintenance issues include adjusting water levels, preventing damage due to wildlife, and performing required tests.

Certification

Operators must have at least a class D wastewater treatment license. During the course of the project, it was noted that the training required to get an operator license does not include the operation of natural systems.

Wildlife control

Wetlands will attract wildlife. Incidents of serious damage to wetland sites were recorded. Muskrats were often the culprit in overgrazing of aquatic plants, breaching of wetland berms, and clogging of pipes. However, with appropriate mitigation efforts, wildlife damage can be minimized

Design

Design Methods

Wetlands were designed primarily for BOD removal. Some sites went through calculations to determine size requirements assuming plug-flow reactions and first-order kinetic relationships.

A two-year study completed in 1994 for the Colorado community of Las Animas provided many systems with empirical data from which to size their systems.

Some systems used the guidelines provided by the CDPHE to size systems based on influent flow rates. The Design Criteria adopted by CDPHE for constructed wetlands systems is shown below.

	Treatment Objectives			
	Secondary Treatment		Advanced Treatment	
System Use	Surface Flow	Subsurface Flow	Surface Flow	Subsurface Flow
	Acres / MGD	Acres / MGD	Acres / MGD	Acres / MGD
Basic Treatment	NA	40-15	NA	$\geq$30
Secondary Treatment	75-20	20-5	$\geq$50	$\geq$20
Polishing Treatment	50-10	20-5	$\geq$30	$\geq$20

CDPHE Volumetric Loading Guidelines

The area to flow ratios for the Colorado treatment wetlands vary considerably, as shown by the table below

Site	**Size**	**Design Flow**	**Acre/MGD**
Avondale	0.87	0.11	7.9
Bennett	2	0.42	4.8
Calhan	0.31	0.8	0.4
Crowley	3.04	0.17	17.9
Crowley Correctional Facility	3.3	0.15	22
Delta Correctional Facility	1.38	0.067	20.6
Dove Creek	1	0.115	8.7
Highland Presbyterian Camp	0.014	0.0005	28
Hi-Lands	0.21	0.055	3.8
Horizon	1	0.015	66.7
Island Acres	1	0.02	50
La Veta	1.6	0.125	12.8
Las Animas	2.1	0.5	4.2
Manzanola	2.3	0.125	18.4
Ouray	0.76	0.363	2.1
Platteville	3	0.348	8.6
Ridgway	1.5	0.015	100
Rocky Mountain Shambhala Center	0.23	0.05	4.6
Silt	0.83	0.236	3.5
Valmont	0.03	0.5	0.1

Shape

Many of the wetlands were retrofit into abandoned lagoons and therefore had to be rectangular. It is often necessary, and at least desirable, to minimize the size of the wetland. To this end, many of the wetlands were compacted into a u-shaped design with a serpentine flow path. This design maximizes the length to width ratios in a minimal area. A few of the wetlands provided islands and irregular borders. These features do not interfere with the water treatment function of the wetland, but they do significantly enhance the wildlife value of a wetland by providing niches for various habitats. These features also add to the aesthetic appeal of a wetland.

Size

The wetlands ranged in size from 0.014 acres to 3.3 acres. Surface flow wetlands typically require more surface area than subsurface flow wetlands. The wetland size must be sufficient to provide the desired water depth and hydraulic detention time.

Hydraulics

Simple piping is always best. The sites visited used typical pipe diameters of 4” to 2” to distribute the wastewater within the wetland cells. Plugging was a common maintenance issue. The piping systems should provide easily accessible clean-out stubs and adequate diameters for jetting (flushing out with high pressure water) out the pipes.

In-flow

Perforated irrigation pipe was commonly used to distribute the flow across the head of the wetland cells. The spacing between the slots can be determined by adjusting the slot openings. Subsurface wetlands typically use dendritic piping down the length of the wetland cells to distribute the influent.

Out-flow

Slotted irrigation pipes, and adjustable weirs were used to collect the effluent from the ends of the wetland cells.

Water Level Control

The ability to adjust the water depth in the wetland was determined to be a crucial matter for the following reasons:

- If needed, detention time in the wetland can be extended by increasing the water depth
- Plant growth can be assisted by lowering the water level in a surface flow wetland to prevent the ‘drowning’ of seedlings, or by increasing the flow depth in a subsurface flow wetland to allow the young roots to establish themselves
- Muskrat infestations can be minimized by allowing wetland cells to dry-up
- Anaerobic conditions can be reversed by lowering the water level

Common water level control devices are shown below.

Swiveling Tees

Collared controls

Levees with removable boards

Water Distribution

Effective operation of the wetland requires the ability of the operator to isolate and bypass system components. This allows systems to be taken off-line for maintenance.

Material Selection

Common materials used were wood boards for level control, pvc pipes, wood for berms, earthen berms, and concrete berms. If the long-term maintenance of the wetland will require burning, material should be chosen in the design phase that will minimize potential damages. For example, wooden berms and pvc pipe stub-outs may need additional protective measures during burns.

Biological Perspective

In general, the treatment wetlands included in the study had healthy vegetation cover, however, the treatment wetlands often lack vegetation diversity. In most of the wetlands included in the study, broadleaf cattail or other aggressive introduced species, are generally the dominant plants. Cattail are aggressive colonizers of wetlands, and form a dense cover quickly. From a wastewater treatment standpoint, this plant is effective because it is easy to establish and maintain. From the standpoint of vegetation diversity and wildlife habitat, however, this plant is not considered by ecologists and wildlife managers to be of high value. Cattail often forms monospecific stands and is so aggressive that other species cannot colonize habitats in which it is dominant. Also, only a limited number of wildlife species use these monospecific stands. Treatment wetlands dominated by cattail are easy to maintain, and function in treating wastewater as well as a more diverse species mix, but from a strictly biological perspective, they do not provide exceptional habitat.

Annual weeds are common in upland areas around almost all of the treatment wetlands. While annual weeds generally are not considered noxious, they are not considered desirable. Treatment plant operators and designers are probably not focused on the maintenance of upland areas between wetland cells and lagoons, but seeding grasses and controlling weeds in these areas would be a good management practice.

In some instances, providing vegetation diversity and wildlife habitat may be at odds with management of a site to treat wastewater. Wildlife use can damage liners of treatment wetlands and dead vegetation harvested by muskrats can clog outflows of treatment wetlands. Also, ease of maintenance and consequently low operating cost is often more important to treatment facilities than vegetation diversity or wildlife habitat. In cases where providing for biological, aesthetic, recreational, and educational resources is important, however, treatment wetlands can be designed to provide these functions.

Human Use and Aesthetics

Wetlands offer ancillary benefits to the communities for which they treat wastewater. These benefits can be enjoyed at minimal additional work and/or cost at the site. Some of the ancillary benefits noted at Colorado wetland sites are:

- Interpretive centers along trails
- Local schoolchildren and touring group field trips
- Science fair projects
- Graduate students’ research projects
- Inmate training

Water Quality Data

This study only reviewed existing data. Most of the systems are consistently in compliance with their discharge permit requirements. Historical data depict a marked improvement in BOD and TSS removal rates for systems that were retrofit to include a wetland system. The average BOD in the system effluent was 20.5 mg/l and the average TSS in the effluent was 27 mg/l.

Also of concern in a wastewater treatment facility are pH, and fecal coliform levels. Typically, s system must maintain pH's in the range of 6-9 in order to minimize disturbances to the receiving water body. Fecal coliform levels are monitored to ensure that microorganisms and viruses are destroyed before discharge. Detention times, and sunlight exposure are often sufficient to reduce fecal coliform levels to permit requirements, without the use of additional disinfection. As a precaution, all the wastewater treatment facilities had the ability to provide some form of disinfection when needed.

Overall System Observations

System Age

The oldest constructed treatment wetland in Colorado is the Horizon Nursing Home system, in the Town of Eckert. This surface flow system was implemented in 1988 and has consistently met its discharge permit requirements since coming online. Plants were healthy and the ecosystem appears to be thriving. The system has not experienced diminishing treatment functions.

Newer systems experience a start-up period in which the wetland plants and microorganisms are becoming established. Until these biological systems are fully developed, the wetland operates as a physical filter. Treatment goals may not be reached during this period.

System Type

Colorado has both subsurface flow surface flow constructed wetland treatment systems. These systems are differentiated by the location of the water surface. In subsurface wetlands, the water surface is within the soil matrix, and is not visible. In surface flow wetlands, the water surface ponds on the soil surface. Both constructed wetland types mimic natural wetland behavior. In a natural wetland, the hydrologic regime varies seasonally. At times of low flow, the natural wetland operates similar to a subsurface wetland. The wetland area may appear dry, and not free standing water will be noted. During times of peak flows, the wetland system will operate similar to a surface flow wetland, with a free water surface flowing through the wetland.

Subsurface

The project team visited three subsurface treatment wetland systems. Some experiences noted by these systems are discussed below.

Costs

These systems are generally more expensive than surface flow systems to construct, however, they require less surface area, which may offset some of the construction costs. Construction costs include excavation, subsurface hydraulic systems, and the installation of a specified soil media. An excerpt from Kadlec and Knight's *Treatment Wetlands*[1] book provides the following cost estimates.

Subsurface Flow				
Item	Units	Unit Price	Total Cost	% of Total
Excavation / Compaction	Yd3	$1.80	13,000	10.7
Soil	Yd3	$1.00		
Gravel	Yd3	$16.10	51,900	42.6
Liner	Acre	$15,000	19,250	15.8
Plants	Each	$0.60	13,330	10.9
Plumbing	Lump Sum		7,500	6.1
Control Structures	Lump Sum		7,000	5.7
Other	Lump Sum		10,000	8.2
			121,980	

Operational Issues

Subsurface systems are prone to plugging problems. During the construction of the wetland, it is important to oversee the soil placement to ensure that the specified particles size is used. Contractors must wash the specified gravel in order to minimize the presence of dust, which may lead to plugging of the system.

Subsurface systems have less freezing potential than surface flow systems. In addition, since there is no open water, vector issues are minimized. These systems will typically avoid mosquito infestations. Since contact of the wastewater with the air is minimized, odors should not be an issue for subsurface systems.

Effectiveness

Many of the subsurface wetlands discharged into leach field, or evaporative fields. Since evaporative and groundwater discharge permits do not require sampling of the discharge (groundwater discharge requires sampling from monitoring wells, which will not show how the wetland itself is operating) there is no conclusive data. The project team did visit some SF wetlands that appeared to be functioning, plants were well established, effluent appeared to be reasonable clear and odorless. However, without the presence of certified laboratory data, it cannot be proven that these systems are meeting the same standards as the regulated surface flow wetlands.

Some of the Colorado SF wetlands that were failing in terms of their ability to effectively treat wastewater were due to

- Overloading, up to five times design flows
- Unwashed media
- Uneven distribution of water in the soil matrix resulted in water level too deep at the inlet to allow plant establishment.

Other subsurface wetlands were rated low from an ecological viewpoint because of the lack of established wetland plants.

[1] Robert H. Kadlec & Robert L. Knight: Treatment Wetlands, Lewis Publishers, Boca Raton, 1996.

Surface

Surface flow wetlands operate similar to a wetland under inundated conditions. Interaction of the water surface with the atmosphere provides for both natural surface aeration and some natural disinfection due to sunlight penetration.

Costs

An excerpt from Kadlec and Knight's *Treatment Wetlands*[2] book provides the following cost estimates. Some costs may be minimized if an abandoned lagoon can be retrofit into a wetland system.

Free Water Surface Flow				
Item	Units	Unit Price	Total Cost	% of Total
Excavation / Compaction	Yd3	$1.80	13,000	19.4
Soil	Yd3	$1.00	2,800	4.2
Gravel	Yd3	$16.10		
Liner	Acre	$15,000	19,250	28.7
Plants	Each	$0.60	7,500	11.2
Plumbing	Lump Sum		7,500	11.2
Control Structures	Lump Sum		7,000	10.4
Other	Lump Sum		10,000	14.9
Total			67,050	

Operational Issues

Some of the wetlands had problems due to muskrat invasion and inability or inappropriate control of water level.

Effectiveness

The majority of the surface flow systems were consistently meeting permit limitations. In addition, the open water provides wildlife and aesthetic value. Most of the surface flow wetlands had healthy plant growth and were deemed to be suitable habitat for wildlife.

Overall Site Features

The table below provides a summary for some of the features of Colorado wetlands visited during this inventory. The bottom line for system effectiveness was 'did it meet permit limitations'. From a biological viewpoint, the wetland was scored based on habitat value. It is noted that sites with high habitat scores tended to also provide reliable wastewater treatment, and conversely, systems with low habitat value tended to provide inconsistent wastewater treatment.

[2] Robert H. Kadlec & Robert L. Knight: Treatment Wetlands, Lewis Publishers, Boca Raton, 1996.

Site	Type	Size (acres)	Design Flow (mgd)	Average Flow (mgd)	Population	Meeting permit limitations	Montana Method Score	Educational Uses	Year Online	Primary Treatment
Avondale	FWS	0.87	0.110	0.080	1000	No	2.4	No	1996	Lagoon
Bennett	FWS / SF	2	0.42	0.80	2200	Not online	2.6	Yes	Not online	Lagoon
Calhan	SF	0.31	0.80	0.065	850	Yes	2.6	Yes	1996	Lagoon
Crowley	FWS	3.04	0.170	0.126	1200	Yes	2.5	No	1996	Lagoon
Crowley Correctional Facility	FWS	3.3	0.150	0.110	600	Yes	2.0	Yes	1998	Lagoon
Delta	FWS	1.38	0.067	0.038	590	Yes	1.3	Yes	1997	Lagoon
Dove Creek	FWS	1.0	0.115	0.035	743	Yes	2.6	No	1999	Lagoon
Highland Presbyterian Camp	SF	0.014	0.0005	0.0005	240	No	0.98	Yes	1996	Septic Tanks
Hi-Land Acres	SF	0.21	0.055	0.022	300	Yes	0.90	Yes	1998	Lagoon
Horizon	FWS	1.0	0.015	0.010	220	Yes	2.2	Yes	1988	Lagoon
Island Acres	FWS	1.0	0.020	0.015	380	Yes	2.6	No	1995	Septic Tanks
La Veta	FWS	1.6	0.125	0.075	850	Yes	2.7	Yes	1993	Lagoon
Las Animas	SF	2.1	0.50	0.25	3500	Yes	2.1	No	1999	Lagoon
Manzanola	FWS	2.3	0.125	0.045	450	No	2.8	No	1998	Lagoon
Ouray	FWS	0.76	0.363	0.26	700 – 2000	Yes	2.6	No	1995	Lagoon
Platteville	FWS	3.0	0.348	0.130	2500	No	2.0	No	1992	Lagoon
Ridgway	FWS	1.5	0.015	0.015	290	Yes	2.8	Yes	1994	Septic Tanks
Rocky Mountain Shambhala Center	SF	0.23	0.05	0.05	200-500	Yes	1.5	Yes	1996	Septic Tanks
Silt	FWS	0.830	0.236	0.110	1700	No	2.3	No	1992	Lagoon
Valmont	SF	0.03	0.50	0.25	100	Yes	2.1	No	1993	Septic Tanks